Morphologically-conditioned tonotactics in multilevel Maximum Entropy grammar

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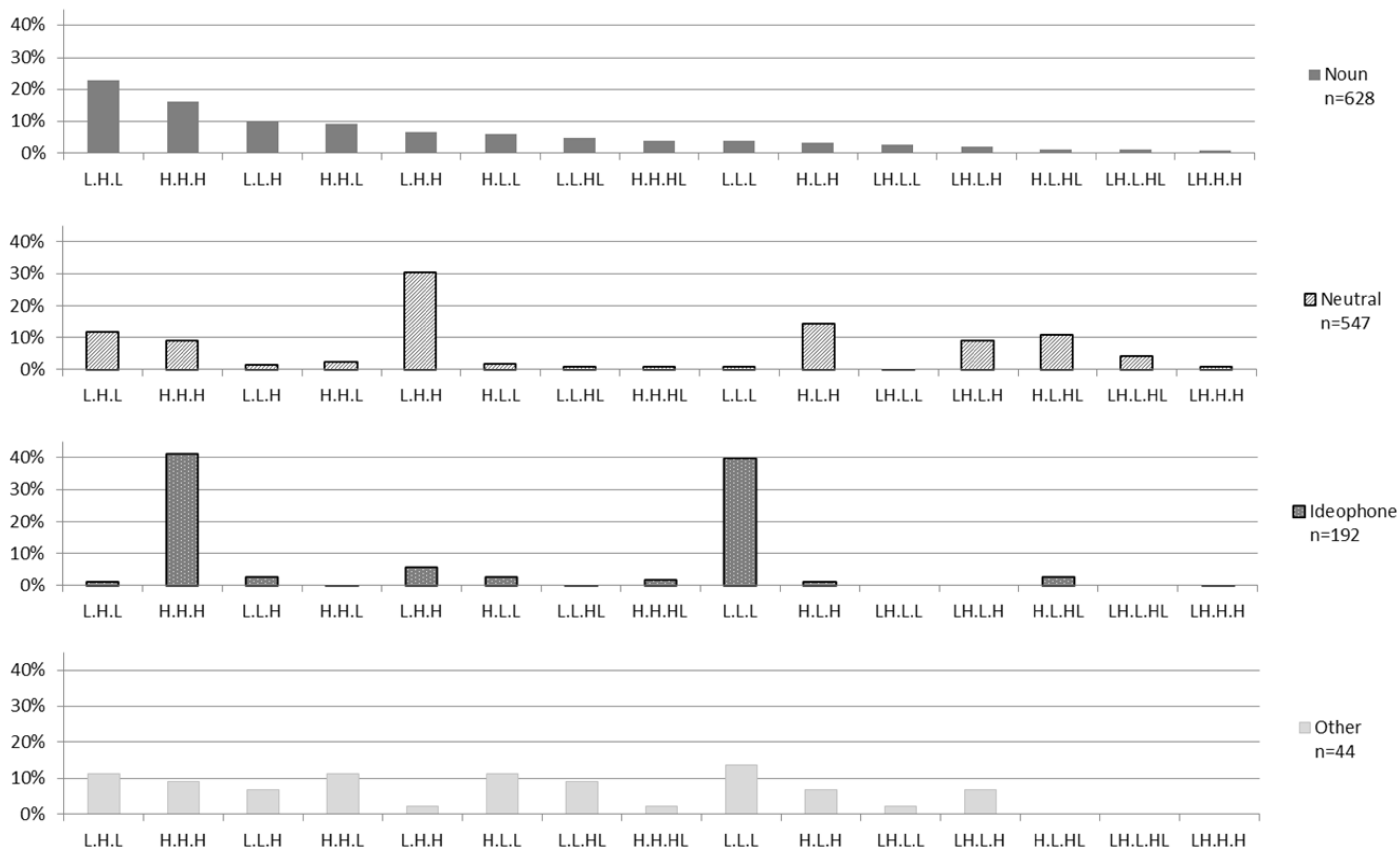
1 INTRODUCTION

❖ This talk presents a case of lexically-conditioned tonotactics variation from Mende (Mande, Sierra Leone).

(1) Top trisyllabic surface tone patterns in the Mende lexicon



- Part of speech-sensitive patterns =
  - different lexical classes can exhibit different phonological patterns.
  - noted cross-linguistically: e.g., English noun versus verb stress patterns
  - applications in e.g., comprehension, parsing

- Two hypotheses about how lexical class-conditioned sensitivity could work:

  A. Lexical class differences are limited by the grammar/UG.
     - differences only in faithfulness, not markedness (e.g., Ito & Mester 1995; Alderete 2001; Smith 2011)
     - preferential classes, e.g., nouns // verbs will show a subset of noun patterns (Smith 2011)

  B. Lexical classes can each have their own completely independent phonological profiles (e.g., Ito & Mester 1995; Inkelas & Zoll 2007; Anttila 2002; Pater 2009).
     ↳ We argue for this latter hypothesis here.

❖ This talk:
- quantitatively models space of lexically-conditioned variation and frequency of variation across the corpus,
- using a ‘varying slopes’ approach in Maximum Entropy Harmonic Grammar (MaxEnt; Goldwater & Johnson 2003; Wilson 2006; Jäger 2007; Hayes & Wilson 2008; a.o.).
- ↳ This approach directly addresses the overarching problem in morphophonology of how to quantify the heterogeneity that morphological conditioning can engender in a phonological system.

2 MENDE TONOTACTICS

2.1 History, early generative accounts

- Early generative accounts of Mende noticed common tone patterns recurrent in the language, particularly in nouns (Leben 1978) → ‘tone melodies’ (see also Hyman 1987 for similar tone melodies in Kukuya),
- In Autosegmental Phonology, these surface tone patterns were modeled using
  - geometric association conventions of Autosegmental Phonology
  - 5 underlying tone melodies (H, L, HL, LH, LHL) as source of all surface patterns.

(2) ndàvúlá ‘sling’ *L→R, 1↔1 association, then spread.*
L H

- But, subsequent work pointed out many surface patterns that deviate from the supposed five melodies or their “universal” autosegmental association principles (Dwyer 1978; Conteh et al. 1983; Zoll 2003; Zhang 2007).

(3) a. lèlèmá ‘praying mantis’ *violates association principles*
L H

b. gbágbɛ̌mà ‘sensitive plant’ *cannot arise from one of the 5 tone melodies; violates association principles*
H LH L

2.2 Data

- Mende dictionary: *n*=5,412 (Innes 1969)
- 1 to 3-syllable words: *n*=4,989
  - Morpheme breaks are not indicated in Innes, but a primary source of morphological complexity (in nouns, at least) appears to be total reduplication in 4-syllable words, which we’re not looking at here.
- Parts of speech
  - Nouns 2,494
  - Neutrals 1,442 (verbs, adjectives)
  - Ideophones 762
  - Other 291 (pronouns, conjunctions, interjections, adverbs, etc.)

2.3 A fresh look at tone: the theoretical underpinnings

- Agreement by Correspondence Theory (ABC; Hansson 2001; Rose & Walker 2004; Bennett 2013; a.o.)
  - grounded in basic principles of similarity and proximity attraction, modeling instability in syntagmatic phonological relationships (Wayment 2009; Inkelas & Shih 2013).
  - Elements that are sufficiently similar/proximal interact in e.g., assimilation/dissimilation.
  - For simplicity in this talk, constraints are reformulated into more familiar phonotactic markedness format (but it’s still ABC under the hood; cf. Hansson 2014).

- Q Theory (e.g., Shih & Inkelas 2014)
  - decomposes segments into strings of (2 or 3) smaller, temporally-sequenced, featurally-uniform subsegments, which bear tone features.

(4) a. Q → (q^1 q^2)
b. ă → (à á)
c. $\widehat{\text{LH}}$ → (L H)

– provides a more fine-grained point of reference for the grammar: crucial for e.g., contour tones.
– divorces issue of what are the minimal units that carry tone features versus what are the units that participate in tonal alternations/phenomena.

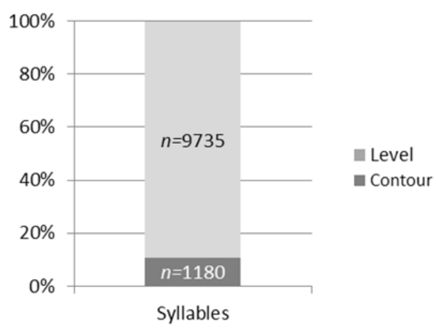
- Basic relevant differences between Autosegmentalism (e.g., Leben 1973) and ABC+Q for this talk:
  – Constraints grounded in principles of similarity- and proximity-based interaction.
  – No reliance on geometric, autosegmental 'line' representations
  – No reliance on operations that reference autosegmental 'lines': i.e., tone association rules.[1]

2.4 Observed patterns for Mende surface tones

- Primary observations taken from Inkelas & Shih 2015.

2.4.1 Contour toned syllables (and tone transitions in general—except at syllable boundaries) are avoided.

(5)



- Significantly fewer contour syllables than expected, if syllable tone patterns could be HH, LL, LH, and HL. χ^2=6705.270, p<0.0001.

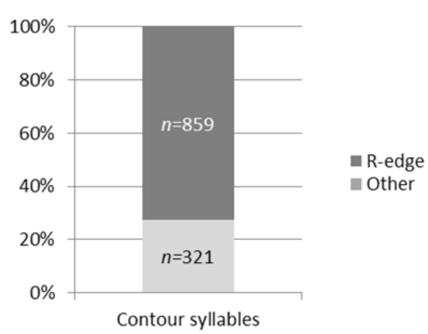
(6) *[αT]::[βT] (*CHANGE) Penalise every sequence of adjacent *q*'s that are tonally non-identical.

(7)

σ.σ	*freq*	*CHANGE *[αT]::[βT]
☞ a. LL.HH	701	1
b. LL.HL	389	W2

2.4.2 If necessary, contour tones are tolerated at the right edge.

(8)



- The significant majority of contour syllables occur at the right edge of words.
- versus equal probability across all syllables: χ^2=353.407, p<0.0001.

[1] This possibility was hinted at by Zoll (2003), but not fully explored.

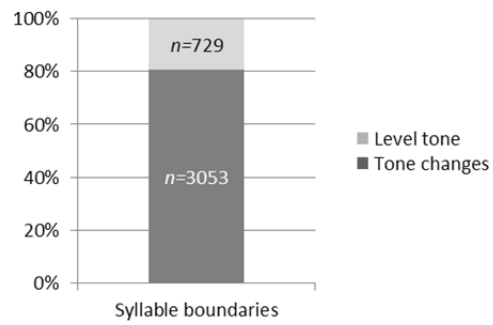
(9) $*([\alpha T]::[\beta T])_{\sigma w}$ (*WeakCONTOUR) Penalise every adjacent *q* sequence of non-identical tones within a weak (i.e., non-final) syllable. (cf. COINCIDE-CONTOUR; Zoll 2003)

(10)

	σ.σ	*freq*	*WeakCONTOUR $*([\alpha T]::[\beta T])_{\sigma w}$	*CHANGE $*[\alpha T]::[\beta T]$
☞ a.	LL.HL	389		2
b.	LH.LL	77	W1	2

2.4.3 Tone changes align with syllable boundaries

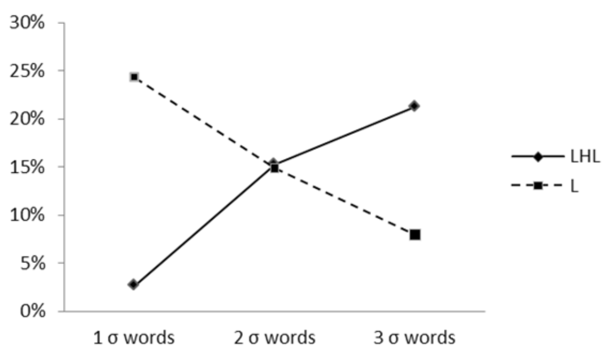
(11)



- Syllable boundaries coincide significantly with tone changes (in polysyllabic words that have non-level surface patterns) . χ^2=1428.074, p<0.0001

- Resulting prediction: tone melody complexity should correlate with the number of syllables in a word. More syllables → more non-level tone patterns (Inkelas & Shih 2015).

(12)



- As # of syllables in a word increases, so does the percentage of more complex melodies. Conversely, less complex, all-level melodies decrease.

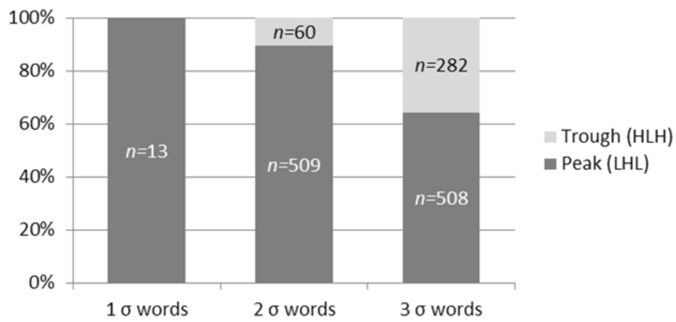
(13) $*[\alpha T]:\$:[\alpha T]$ (CHANGE@$) Penalise every adjacent, tonally-identical *q* sequence that is separated by a syllable boundary ($). (cf. xx-Edge constraints; Bennett 2013)

(14)

	σ.σ.σ	*freq*	CHANGE@$ $*[\alpha T]:\$:[\alpha T]$	*WeakCONTOUR $*([\alpha T]::[\beta T])_{\sigma w}$	*CHANGE $*[\alpha T]::[\beta T]$
☞ a.	LL.HH.LL	233			2
b.	LL.HH.HH	218	W1		L1
c.	LL.LL.LL	112	W2		L
d.	LL.LL.HH	78	W1		L1
e.	LH.LL.HH	64		W1	W3
f.	LH.HH.LL	7	W1	W1	2

2.4.4 HLH troughs are avoided

(15)

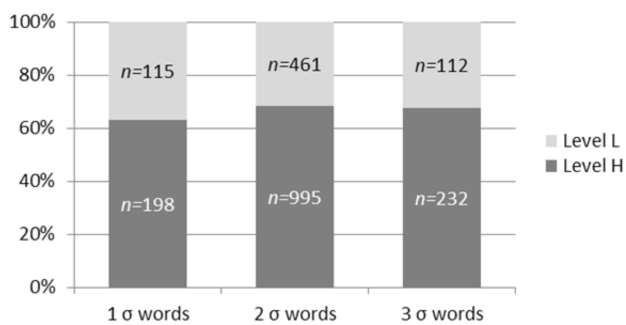


- Troughs are underrepresented, but their presence increases as the number of syllables in words increases.

(16) *TROUGH Penalise any two H tones separated by any number of consecutive L tones. (Cahill 2007; a.o.)

2.4.5 Words preferably have at least one H tone

(17)



- Level H tone patterns (e.g., HH.HH.HH) are more common than Level L tone patterns (e.g., LL.LL.LL).

(18) HAVEH Penalise any word with no H tone.

2.5 Constraint summary

(19)

Constraint	Nickname	Definition
*[αT]::[βT]	*CHANGE	Penalise every sequence of adjacent *q*’s that are tonally non-identical.
$*([\alpha T]::[\beta T])_{\sigma w}$	*WeakCONTOUR	Penalise every adjacent *q* sequence of non-identical tones within a weak (i.e., non-final) syllable.
*[αT]:$:[αT]	CHANGE@$	Penalise every adjacent, identical *q* sequence that is separated by a syllable boundary.
*TROUGH	*TROUGH	Penalise any two H tones separated by any number of consecutive L tones.
HAVEH	HAVEH	Penalise any word with no H tone.

- Note that no matter the OT analysis, the goal in this paper is to examine and model the variance of part-of-speech-specific tonotactics. (Almost) any constraint set would be fine for this, and the fact that there’s lexically-conditioned differences (see (1)) doesn’t change.

3 ANALYSIS

3.1 Maximum Entropy Harmonic Grammar

- Maximum Entropy Harmonic Grammar (MaxEnt) (Goldwater & Johnson 2003; Wilson 2006; Jäger 2007; Hayes & Wilson 2008; a.o.), fitted using MaxEnt Grammar Tool (Hayes et al. 2009).[2]
  - ranks probabilities (i.e., comparative grammaticality) of outcome candidates in variable data.
- Output = probability distribution over all possible surface tone pattern combinations of LL, HH, LH, HL syllables (LHL, HLH are found on monosyllables only)

3.2 Cophonologies/Indexed Constraints as Varying Slopes

- Varying slopes = additive weight adjustment for constraints in the Base Grammar, per each lexical class.
  - Such an approach has been hinted at before: e.g., Albright 2008; Coetzee & Pater 2011.

(20) $$w_1C_1 + w_2(C_1 \times \textsc{Noun}) + w_3(C_1 \times \textsc{Neut}) + w_4(C_1 \times \textsc{Id}) + \cdots + w_kC_{iN}$$ (cf. fn 2)

Base grammar	=	w_1C_1
Adjusted noun grammar	=	$w_1C_1 + w_2(C_1 \times \textsc{Noun})$
Adjusted neutral grammar	=	$w_1C_1 + w_3(C_1 \times \textsc{Neut})$
Adjusted ideophone grammar	=	$w_1C_1 + w_4(C_1 \times \textsc{Id})$

- Base Grammar predicts overall tonotactics for the language, and lexical class-specific tonotactics are predicted by the additive combination of weights of Base Grammar constraints and class-specific weights.
- Cophonologies ≅ bundles of Indexed Constraints.
- Because there is a finite set of lexical classes, varying slopes are formally executed here as interaction terms.[3]
  - for other previous uses of interaction terms in MaxEnt HG, usually as weighted constraint conjunction: see e.g., Hayes et al. 2012; Pater & Moreton 2012; Green & Davis 2014; Shih, to appear.

3.3 What is the base grammar?

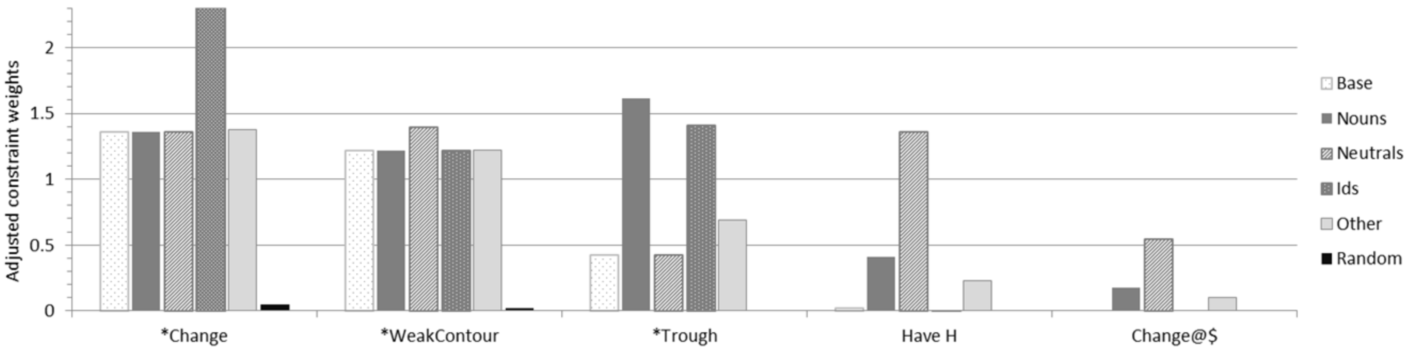
- Trained a base grammar on bootstrapped samples (*n*=2500 / sample) of possible tone melodies in Mende, drawn from the existing distribution.
  - mirrors a Mende speaker knowing word tone patterns but not (yet) part of speech.
  - did not want to *a priori* assume one lexical class as "default."
  - across base grammar samples, the results are stable; a representative result is reported here.

- A grammar trained without any data for base grammar provides very similar results (not reported here).
- Another baseline: grammar on a totally random tone patterns (*n*=5000), generated from random combinations of HH, LL, LH, and HL syllables for 1–3 syllable words is also provided here for comparison.

[2] $\mathcal{H}\text{armony}(x, i) = \sum_{k=1}^{N} w_k C_i(x) = \boldsymbol{w_k} \cdot \boldsymbol{C_i}$; where x = candidate for input i, w_k= weight of constraint C_i, $C_i(x)$ = number of violations of C_i that x incurs, and N = vector of constraints $(C_{i1} \ldots C_{iN})$.
[3] For justification on the equivalency of interaction terms and random slopes in this situation, see e.g., Gelman & Hill 2007.

4 RESULTS

(21) Adjusted MaxEnt weights, in graphical form
(adjusted wC_i = base wC_i + indexed wC_i)



(22) Adjusted MaxEnt weights, in numbers

	Base	Adjusted Grammars				Random
		Nouns	*Neutrals*	*Ideophones*	*Other*	
*CHANGE	1.356	1.356	1.356	2.537	1.374	0.047
*WeakCONTOUR	1.220	1.220	1.391	1.220	1.220	0.018
*TROUGH	0.426	1.612	0.426	1.409	0.691	0
HAVE H	0.017	0.411	1.361	0.017	0.232	0
CHANGE@$	0	0.175	0.543	0	0.099	0

(23) Constraint weights by lexical class (top→bottom: highest weight→lowest weight)

Base	Cophonology Indexed Grammars			
	Nouns	*Neutrals*	*Ideophones*	*Other*
*CHANGE	*TROUGH	*WeakCONTOUR	*CHANGE	*CHANGE
*WeakCONTOUR	*CHANGE	HAVE H	*TROUGH	*WeakCONTOUR
*TROUGH	*WeakCONTOUR	*CHANGE	*WeakCONTOUR	*TROUGH
HAVE H	HAVE H	CHANGE@$	CHANGE@$	HAVE H
CHANGE@$	CHANGE@$	*TROUGH	HAVE H	CHANGE@$

4.1 Results and observations

4.1.1 Sanity check

- A MaxEnt grammar on completely random data yields constraint weights pretty close to 0.

4.1.2 Base grammar

- Reveals importance of general contour tone avoidance and R-edge contour tone alignment.
  - *CHANGE = 1.356
  - *WeakCONTOUR = 1.220
  - cf. "Random" model results, where weights are much lower, nearly at 0.
- These two constraints remain highly weighted across all lexical classes.
  - weight of *WeakCONTOUR stays stable across the lexicon, suggesting that it's a very general principle.
- Reflects universal dispreferences for (nonfinal) contour tones (e.g., Gordon 2001; Zhang 2004).

4.1.3 Syllable edge – Tone change alignment

- Only nouns and neutrals show an effect of syllable edge-tone transition alignment. → see adjusted weights for CHANGE@$:
  - CHANGE@$×NOUN = 0.175
  - CHANGE@$×NEUT = 0.543
  - versus CHANGE@$×ID = 0

- Shows that ideophones often involve much simpler surface tone patterns than the other lexical classes.
  - e.g., *vòvòlò* ‘creaking’
  - In addition, ideophones significantly increase the weight of *CHANGE

(24)

σ.σ.σ, ID	*freq*	*CHANGE×ID *[αT]::[βT]×ID w_{adj}=2.537	CHANGE@$×ID *[αT]:$:[αT]×ID w_{adj}=0	$\mathcal{H}$
a. LL.HH.LL	2	W2		**5.073**
☞ b. LL.LL.LL	76		L2	**0**

4.1.4 HAVE H*: a verb thing*

- Neutrals in particular (but also nouns to a certain extent) show a much greater affinity for a requisite H tone than ideophones.
  - = level L surface patterns much more tolerated for Ideophones > Nouns > Neutrals.

(25)

σ.σ.σ, NEUT	*freq*	HAVEH×NEUT w_{adj}=1.360656	$\mathcal{H}$
a. LL.LL.LL	5	1	**1.36**

σ.σ.σ, NOUN		HAVEH×NOUN w_{adj}=0.410611	
b. LL.LL.LL	25	1	**0.41**

σ.σ.σ, ID		HAVEH×ID w_{adj}=0.016843	
c. LL.LL.LL	76	1	**.02**

4.1.5 *TROUGH*: not a verb thing*

- Neutrals also differ from Nouns and Ideophones by showing greater preference for tone transitions that align with syllable boundaries, even if these result in a HLH trough.
  - e.g., *húvùndí* ‘be mouldy, mildewed’
  - = Greater dispreference of troughs in Nouns and Ideophones.
  - Much lower adjusted weight for *TROUGH in Neutrals than other lexical classes:
  - *TROUGH ×NEUT = 0.426
  - *TROUGH ×NOUN = 1.612
  - *TROUGH ×ID = 1.409

- Perhaps a contrast maximization issue?

(26)

		σ.σ.σ, Neut	*freq*	*Trough×Neut w_{adj}=0.426	Change@$ *[αT]:$:[αT]×Neut w_{adj}=0.543	$\mathcal{H}$
a.	☞ i.	HH.LL.HH	78	1		**0.43**
	ii.	HH.HH.HH	48		**2**	**1.09**

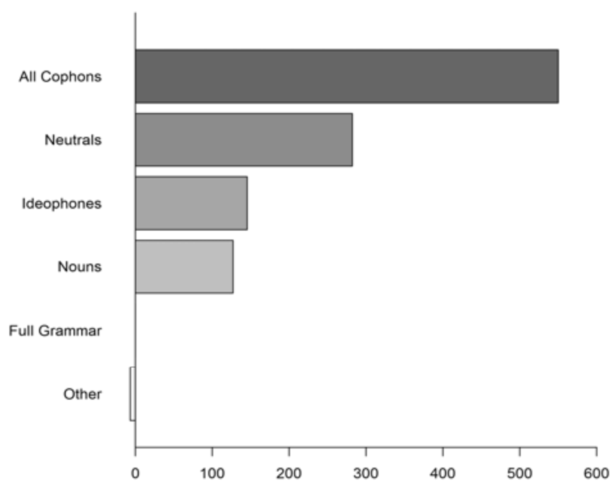
		σ.σ.σ, Noun		*Trough×Noun w_{adj}=1.612	*[αT]:$:[αT]×Noun w_{adj}=0.175	
b.	i.	HH.LL.HH	21	1		**1.61**
	☞ ii.	HH.HH.HH	101		**2**	**0.35**

		σ.σ.σ, Id		*Trough×Id w_{adj}=1.409	*[αT]:$:[αT]×Id w_{adj}=0	
c.	i.	HH.LL.HH	2	1		**1.41**
	☞ ii.	HH.HH.HH	79		**2**	**0.00**

4.2 Importance of lexical conditioning

- Are the cophonology/indexed grammars contributing significantly to improving our base grammar?
- Tested here using Akaike Information Criterion (AIC_C) model comparison.[4]
  - How much information is lost when cophonology/indexed constraints are removed?

(27) ΔAIC_C from full model for each cophonology removed
= how much information is lost for each cophonology is in turn removed.[5]



- AIC_C comparison results show that lexical class-specific cophonologies/indexed constraints produce a better fit for the data.
  - Exception that is expected: the “Other” part of speech class, which is heterogeneous as is.
- Certain lexical classes provide more information on top of the baseline, suggesting ‘distance’ from the full model.
  - Neutral-specific cophonology contributes a lot of additional information to the grammar.
  - Interestingly, ideophones are *not* the most extreme lexical class.
- For future work: comparing individual indexed constraints versus entire cophonologies of indexed constraints.

[4] Second-order AIC_C is used here, because it adjusts more strictly for differences in the number of constraints between comparison grammars. See e.g., Burnham & Anderson 2002 for justification of AIC_C-based model comparison. For use in comparing phonological grammars, see e.g., Shih, to appear (cf. Wilson & Obdeyn 2009).

[5] $\Delta AIC_C \geq 10$ is considered large (equivalent to 150:1 that the second best model has essentially no support of being as good as the best model).

5 IMPLICATIONS & CONCLUSION

Lexically-conditioned phonology

- Part-of-speech phonological differences go beyond noun-adjective-verb distinctions (as observed by e.g., Smith 2011).
  - ↳ more closely resemble the complexity of morphophonological alternations and variation.

- Lexically-conditioned phonology is not just a matter of differential faithfulness (e.g., $\text{FAITH}_{\text{NOUN}} \gg \text{FAITH}_{\text{VERB}}$; Smith 2011).
- Overall, indexation of markedness constraints per lexical class gains better fit for the data.
- There are hints of markedness reversals of the kind that 'Grammar Dependence' (Alderete 2001) predicts impossible (cf. Pater 2009):
  - – E.g., Across nearly all of the grammars (base and lexical class-specific) in Mende, *TROUGH is ranked fairly highly w/r/t the other constraints.
  - – In Neutrals, however, *TROUGH is weighted at the bottom.
  - ↳ Therefore, a structure (e.g., HLH) that might otherwise be highly marked in the rest of the language is quite good and (comparatively) unmarked for Neutrals.

Quantifying morphological conditioning

- Our approach can quantify how much lexical class-specific phonotactics can differ from the rest of the lexicon.
  - – E.g., how different can ideophone phonology be? → long standing issue for e.g., African languages (see Rose 2015 for recent summary).
  - – Results show that ideophones operate within fairly conservative parameters of the overall Mende tonotactics grammar—cf., neutrals.
  - – Potentially useful as a scale of ideophone idiosyncrasy (cf. Newman 2001 on Hausa ideophones).
- Because we *a priori* restrict standard HG/OT grammars to positive weights (i.e., to only penalise rather than reward structures), we're not really examining the full potential space of variation between cophonologies yet.
- In the future, this 'varying slopes' approach could extend to other types of morphology (e.g., affixation; dominant tone melodies): e.g., what are the tone patterns that are grammaticalised in a language as productive morphemes?

For the future

- What is the utility of these phonological differences between groups?
  - – There's evidence from other languages that speakers are capable of learning these lexical statistics (e.g., Coetzee 2014),
  - – and that such phonological differences help in e.g., acquisition, processing, information load (e.g., Monaghan et al. 2010).

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To save trees, references are available online.
http://cogsci.ucmerced.edu/shih/ShihInkelas_AMP2015handout.pdf

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